AN ANALYSIS OF THE UTILIZATION OF THE IN-FLIGHT TECHNICIAN IN THE P3C COMMUNITY

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THESIS

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THE IN-FLIGHT TECHNICIAN IN THE P3C
COMMUNITY

by

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This thesis investigated the number of In-Flight-Technicians assigned to a Navy P3C squadron, their contributions to the squadron's ASW capability in their dual roles as in-flight and ground repairmen, and the adequacy of the In-Flight-Maintenance-Kit. Tradeoffs between the number of In-Flight Technicians and ground avionics workers were evaluated as were various methods of the In-Flight Technician's ground and airborne utilization. Potential benefits associated with In-Flight Technician assignment

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I. INTRODUCTION

A. GENERAL

In these times of increasingly scarce and expensive resources, managers at all levels in any organization must concern themselves with ensuring the most productive use of men, money and material. This challenge is applicable to the Naval manager as well as his counterpart in the civilian business community. This paper examines the utilization of the Navy's most valuable asset, manpower, and investigates various methods of manpower employment in one segment of the Naval community.

B. AIRBORNE ANTI-SUBMARINE-WARFARE AND THE P3C AIRCRAFT

United States airborne Anti-Submarine-Warfare (ASW) missions are conducted using two types of aircraft; fixed wing and rotary wing (helicopters). Fixed wing ASW aircraft operate from both land bases and aircraft carriers. The P3C is the Navy's primary fixed wing ASW aircraft operating from land bases.

The P3C Orion is today's most sophisticated airborne ASW weapon system. Developed by Lockheed Aircraft Corporation, the P3C is a military adaptation of Lockheed's commercial airliner, the 'Electra'. The four engine turbo-prop configuration and its advanced communications and navigations systems allow operation of the aircraft in all types of weather from nearly any type of airfield. It is a long

range, long endurance aircraft with a normal ASW mission time of ten hours although twelve hour flights are not uncommon. The primary mission of the P3C, as stated by Naval Instruction[1], is to search out, localize, track and, if necessary, destroy enemy submarines. Its secondary mission is surveillance and tracking of enemy surface units. The P3C is also designed to be relatively self-sufficient to the point that it may operate for short periods of time, usually up to two weeks, from advanced bases where the only items available are fuel, oil and a runway.

The crew of the aircraft, stated in the P3C Natops Flight Manual[2], includes three pilots, one of whom is the Patrol Plane Commander who is responsible for the safe and successful completion of the mission. Additionally there are three sensor equipment operators, two flight engineers, an ordnance man, a Navigations/Communications officer, an in-flight electronics repairman and a Tactical Coordinator who is responsible for target prosecution including data evaluation and strategy selection.

C. MAINTENANCE ORGANIZATION AND REQUIREMENTS

Nine P3Cs are assigned to each of the Navy's Patrol Squadrons. The squadrons, headed by the Commanding and Executive Officers, are organized into three departments:

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[1]OPNAVINST C5442.4D, Subject: Aircraft Material Conditions, Standards and Mission Essential Sub-Systems List, 14 March 1975.

[2]Natops Flight Manual, Navy Model P3C Aircraft.

Operations, Administration, and Maintenance. The Maintenance Department acts as a service organization; its purpose is to provide operationally capable aircraft to the Operations Department for assignment to ASW flight operations. As aircraft material malfunctions arise the Maintenance Department strives to correct the discrepancies as rapidly as possible. The more expeditiously that repairs are effected by the Maintenance Department the higher the degree of aircraft availability for operational assignment. Efficient personnel utilization is a must for the Maintenance Department to fulfill its requirements. This investigation is concerned with one aspect of personnel utilization within the Maintenance Department and examines the impact of personnel allocation on the squadron's ability to conduct ASW operations.

There are three levels of maintenance prescribed in the Naval Aviation Maintenance Program[3]: Organizational, Intermediate, and Depot. Organizational Level maintenance is performed on-board the aircraft by squadron Maintenance Department personnel and is usually the least sophisticated of the three levels. The Maintenance Department is organized into six primary Work Centers, each with a separate area of responsibility. The Work Centers, their areas of responsibility, and enlisted ratings assigned are displayed in Table I-1. It should be noted that Work Centers 210 and X-20 are staffed

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[3]OPNAVINST 4790.2, Subject: Naval Aviation Maintenance Program, 18 June, 1973.

Patrol Squadron Work Center Organization

Work Center			
Number	Name	Enlisted Rates	Areas of Responsibility
110	Powerplants	ADJ	Engines, propellers
120	Airframes	AMS AMH	Aircraft structures, hydraulics
210	Avionics	AT AX	Airborne electronics systems
220	Electric	AE	Electrical and instruments systems
230	Ordnance	AO	Weapons carriage and release systems
X-20	In-Flight Technicians	AT AX	Airborne electronics systems

Table I-1

by the same enlisted rates and each performs maintenance on the P3C's airborne electronics or 'avionics' systems. However, there are very definite differences between the two Work Centers.

The primary difference is the location of work performance. System malfunctions repaired on the ground are corrected by Work Center 210 personnel; those repaired in-flight are corrected by personnel from Work Center X-20.

The second difference is the qualification of the personnel assigned to the Work Centers. Work Center X-20 is manned by the electronics repairman (AT or AX rating) assigned to each flight crew, commonly called the 'in-flight technician' or IFT. His pay grade must be E-5 or above and prior to

squadron assignment he receives thirteen weeks of extensive training on the repair of the P3C avionics systems[4]. Since he is in a flight status the IFT also receives flight pay. Work Center 210 is partially manned by permanently assigned personnel with the same rating as those in Work Center X-20. However, there is no requirement that they be E-5 or above, they do not receive flight pay and their pre-squadron training is far less extensive than that of the IFTs. To complete the manning of Work Center 210, IFTs not engaged in flight operations are assigned to the Work Center to augment the permanently assigned ground personnel. Thus P3C avionics maintenance at the Organizational Level is performed by two groups, IFTs and ground personnel, with IFTs being the more costly of these two manpower resources because of their pay grades, flight pay and added training. Each squadron has the option of varying the allocation of IFTs between Work Centers X-20 and 210 by choosing different policies regarding their airborne utilization (the less an IFT flies the more he is available to Work Center 210).

D. PURPOSE

This thesis investigated the utilization of avionics repair personnel employed in the maintenance of the P3C system. The purpose of the investigation was to estimate the allocation of avionics maintenance manpower which

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[4]NAVEDTRA 10500 Vol. III, C-102-3575, Subject: Catalogue of Navy Training Courses.

maximized the operational capability of a typical P3C squadron. Specifically, the squadron-level allocation of IFT effort in airborne and ground repairs was examined to determine if an optimal allocation existed. This thesis also considered changes in avionics resource allocations beyond the scope of the squadron-level decision maker. These changes included: making additional spare parts available to the IFT while airborne to enhance his repair effort, altering the mix of IFTs and ground personnel assigned to each squadron, and assigning IFTs to Intermediate and Depot Level maintenance activities.

II. ALTERNATIVES

A. GENERAL

The various methods of utilization of the Maintenance Department's avionics maintenance personnel fell into two general categories: use within the squadron and use outside of the squadron. The alternatives within each of these categories were evaluated in order to enhance the squadron's mission performing capability by improving the allocation of avionics maintenance personnel.

B. AVIONICS MAINTENANCE PERSONNEL UTILIZATION WITHIN THE SQUADRON

In the short run the only change possible for the squadron is the re-allocation of its available personnel. Ground avionics personnel receive no in-flight maintenance training which restricts their use to ground maintenance. However, the allocation of IFT time may be varied, at the squadron's option[5], between ground and in-flight maintenance. The allocation of IFT use is determined by the selection of a policy regarding the types of flights on which he is required to fly. The amount of time that IFTs are available for performing ground maintenance varies inversely with their utilization in-flight. Therefore, the short run

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[5] COMFAIRWINGSPAC INSTRUCTION 4790.7, Subject: P3C ASW Weapon Avionics Maintenance; policies concerning, 15 June 1972.

options available to the squadron for utilization of its avionics maintenance personnel range from IFT use solely in the air to assignment of IFTs to Work Center 210 only and all the possible mixes between these extremes.

Even though the IFT is the only asset whose use may be varied in the short run, it must be noted that in the long run the composition of the entire avionics work force could be altered. Thus, changes in ground avionics personnel utilization may also be considered. This is especially important since the ground avionics worker, who does not receive flight pay or additional training, is a less expensive resource than the IFT. The long term alternatives for avionics personnel utilization involves tradeoffs between the numbers of IFTs and ground maintenance personnel assigned to a squadron. The extremes of the possible tradeoffs are a Maintenance Department avionics work force composed entirely of IFTs or entirely of ground personnel.

C. AVIONICS MAINTENANCE PERSONNEL UTILIZATION OUTSIDE OF THE SQUADRON

Since policies regarding assignment of ground personnel outside of the squadron already exist, this thesis only addressed the potential for IFT utilization beyond Organizational Level maintenance.[6] Because all P3C systems maintenance including that at the Intermediate and Depot

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[6] OPNAVINST 4790.2, Subject: Naval Aviation Maintenance Program, 18 June 1973.

Levels enhances the aircraft's ASW capability and the squadron's operational effectiveness and since the IFT receives different and more extensive training than ground avionics maintenance personnel, the possible gains in ASW capability associated with IFT assignment to these maintenance levels were examined. The alternatives available ranged between the extremes of leaving all of the IFTs in the squadron and assigning none to Depot or Intermediate Level maintenance activities to the assignment of all of the IFTs to maintenance billets outside of the squadrons. The two maintenance levels were examined independently and no investigations were conducted regarding IFT assignment tradeoffs between Depot and Intermediate Level maintenance activities.

III. AVIONICS MAINTENANCE PROCESS AND THE P3C

A. THE IFT AND THE P3C

The most significant advance in ASW capability associated with fleet introduction of the P3C is the improved efficiency of time utilization resulting from incorporation of a computerized data processing package into the aircraft's avionics system. ASW missions with the fixed-wing predecessor of the P3C required approximately eighty-five percent of the aircrew's operational flight time for charting courses, plotting targets, keeping logbooks and processing data while only fifteen percent of their time was available for strategy selection and decision making. With the advent of the speed and handling capacity of the P3C's data processing equipment the ratio of time utilization during an operational evolution has been reversed; eighty-five percent of the on station time is now available for strategy selection and decision making.

In order for the P3C's data handling system to accomplish such a drastic improvement in time utilization efficiency it was necessary to tie virtually all of the aircraft's avionics systems to the central data processing package. As a result of this linking of systems, system maintainability became critically important since a single malfunction could have repercussions throughout the aircraft. To improve system reliability the avionics components were designed

for in-flight maintainability and the IFT was added to the normal operating flight crew. To facilitate IFT repair work, additional test equipment was built into the aircraft. The total system was further engineered to permit automatic testing using the aircraft's own computer. In addition to test capabilities aboard the aircraft, an in-flight maintenance kit was also placed aboard in order to supply needed replacement parts and additional test equipment.

The IFT fills two roles in which he contributes to the squadron's operational capability. In the air as a member of Work Center X-20 the IFT has the training, the test facilities and the spare parts to repair many avionics discrepancies which degrade an aircraft's ASW capability, thus allowing completion of the mission. When assigned to Work Center 210 on the ground the IFT enhances the squadron's mission performing capability by increasing the number of aircraft available for mission assignment through his repairs to the avionics systems. When assigned to Work Center 210, the IFT, because of his higher rate, training, and experience level, serves as a part time Work Center supervisor and is instrumental in maintaining Work Center efficiency and effective on-the-job-training for newer avionics personnel.

B. MEASUREMENT OF WORKER OUTPUT

The IFT documents his work output in the same manner as other Maintenance Department personnel, by completing a

Maintenance Action Form (Appendix A) for each repair he performs. The man-hours he expends in the air are credited to Work Center X-20, those on the ground to Work Center 210. The worker output of Work Centers X-20 and 210, as well as the other Maintenance Department Work Centers, is currently determined by measuring the number of man-hours each Work Center member documents each month. While this determination is easy to make, it does not give a true indication of worker output, particularly for Work Centers X-20 and 210, because it fails to relate that output to the squadron's mission performing capability. For example, assume two workers, A and B, work four hours and one hour respectively. Measuring man-hours indicates that worker A is the greater producer. However, assume further that he repaired a relatively insignificant malfunction whereas worker B corrected a discrepancy that had rendered the aircraft completely inoperative. Clearly worker B has done more for the squadron's mission performing capability even though he worked only one hour. Additionally, since IFTs and ground avionics personnel received different training and therefore work on different avionics systems, the measurement of their work effort by examination of man-hours is even more misleading. To better measure worker output and to relate that work to mission performing capability, it was necessary to consider both the number of malfunctions a worker repairs and the significance of those malfunctions in terms of their impact on the squadron's

ASW capability.

C. A MEASURE OF EFFECTIVENESS

1. Objective of Investigation

The objective of this investigation was to determine how a P3C squadron's mission performing capability may be enhanced through the most effective utilization of its avionics maintenance personnel. The squadron's mission performing capability is a direct function of the number of ASW capable aircraft available for operational use. As operational missions were flown the aircraft experienced system discrepancies which reduced aircraft ASW capability. ASW capability lost through avionics systems malfunctions was recovered through repair of those malfunctions, either in-flight or on the ground, by squadron avionics maintenance personnel.

2. Development of the Measure of Effectiveness

a. General

The Measure of Effectiveness was developed to evaluate the contribution of the avionics maintenance process to the squadron's mission performing capability. To do so it was necessary to establish a relationship between the maintenance effort and the squadron's ASW capability. Since avionics maintenance contributes to the squadron's ASW capability by restoring lost ASW capability through malfunctions repaired it was necessary to determine how many system discrepancies were repaired and how much

capability was recovered by those repairs.

b. Assumptions

Since information was gathered from different organizational units, the following assumptions were made to ensure the comparability of the organizations:

(1) <u>Quality of Maintenance</u>. The same quality of maintenance was expected at different organizations. This implies that a particular Maintenance Department, because of the faulty initial repair of a malfunction, would not be expected to recover an unusually high degree of ASW capability through repeated repair of the same malfunction.

(2) <u>Distribution of Malfunction Significance</u>. The same distribution of the significance of malfunctions was expected to occur at different organizations. This implies that a given activity would not recover greater ASW capability than another merely because it experienced a greater proportion of malfunctions that critically affected an aircraft's ASW capability.

c. Presentation of the Measure of Effectiveness

To evaluate the gain in squadron mission performing capability due to avionics maintenance it was necessary to examine the impact of each repair on ASW capability and to total that impact over all repairs. The Equivalent Aircraft Unit (EAU) was developed to serve as the unit of measurement. If two malfunctions, each causing a 50% ASW capability degradation were repaired then those

repairs recovered one EAU. The EAU then is a measure of the number of repairs and the significance of the systems repaired.

Based on the above assumptions that the same quality of maintenance is expected at each activity and that each activity experiences the same distribution of the significance of its malfunctions, an increase in the number of EAUs recovered indicates a greater Maintenance Department contribution to the squadron's ASW capability.

3. Advantages and Limitations

As a measure of effectiveness the EAU is superior to a simple calculation of maintenance man-hours. The EAU gives a direct indication of the maintenance contribution to squadron mission performing capability. Man-hours of maintenance performed are not related to ASW capability.

However, there are two limitations associated with use of the EAU as a measure of effectiveness:

a. Malfunction Independence

Each malfunction was treated as an independent event. The ASW capability restored by the repair of a malfunction was independent of the concurrent existence of other discrepancies. This treatment was implemented to avoid the complexity of simultaneous evaluation of all malfunctions existing on an aircraft. This simplification eliminated the direct relationship between maintenance actions and individual aircraft capability. However, there still exists a direct relationship between maintenance and

total squadron ASW capability. For example, the repair of an aircraft's radar system may recover .5 EAUs for the squadron even though the aircraft in which it is installed is in a non-flyable status due to an engine malfunction. The essence of this limitation is that EAUs are recovered on a system by system basis, not on an aircraft by aircraft basis. Even though the ASW capability of that aircraft was not actually enhanced, after the repair the squadron had one additional operable radar system available for use on another aircraft.

b. Rate of Recovery of ASW Capability

The elapsed time between the occurrence and the repair of a malfunction was not a factor in the measure of effectiveness. Thus no evaluation can be made regarding the rate with which EAUs were recovered. A repair performed on the day that the malfunction occurred was treated the same as an identical repair that was completed days after the malfunction was discovered, even though the ASW capability was lost for a longer period of time.

IV DEVELOPMENT OF MALFUNCTION DATA

A. DATA SOURCES

1. The Maintenance Action Form

The basic documentary source for maintenance related malfunction data is the Maintenance Action Form (MAF). The MAF is utilized by Organizational Level maintenance units to establish a basic record of each malfunction and the related action that occurs. The information recorded on a MAF includes a brief discription of the malfunction, the part numbers of any components replaced, when the malfunction was discovered (i.e. in the air or on the ground), the work center responsible for the corrective action and the signatures of the personnel who accomplished the corrective maintenance. A complete description of the information contained in a MAF is included in Appendix A. After the corrective action is completed, the MAF is retained by the unit responsible for organizational level maintenance. The P3C maintenance and malfunction information is maintained by the squadron which is responsible for Organizational Level maintenance.

2. Squadron Operating Policies

Two P3C squadrons provided access to their MAF files in support of this investigation. During the course of data collection it became apparent that the two squadrons utilized different IFT allocation policies. As this thesis compared the effectiveness of those policies, the squadrons were identified as "Squadron A" and "Squadron B" in order

to preserve their anonymity. Squadron A had elected to fly their IFTs only on operational (ASW) missions, thus causing the IFTs to spend the bulk of their time working on the ground as part of work center 210. Squadron B elected to maximize the IFTs' airborne time by requiring an IFT to fly on all flights regardless of the mission. This policy resulted in less IFT time on the ground in Work Center 210.

In order to determine why the squadrons differed in their utilization of IFTs, discussions were held with representatives of each squadron. Representatives of Squadron A revealed that they felt more could be gained by having the IFTs available for use in Work Center 210 than flying him on all flights because the only time that the IFT could be useful in the air was when ASW related equipment was utilized. This occurred only on operational flights. Representatives of Squadron B felt that ASW related equipment could be tested on all flights, including non-operational ones, and therefore IFTs should be aboard the aircraft for all flights.

3. Summary of Data

The data was collected from each Squadron's records spanning a two month period for each of their nine aircraft. January and February of 1975 were selected since each squadron agreed that those months were typical of the squadrons normal operating environments.

Over 1100 MAFs were examined of which 715 were considered relevant for analytical purposes. The remainder involved 'trouble-shooting' and 'Cannibalization' action.

Cannibalization is the exchange of defective equipment of one aircraft with operable equipment from another aircraft while trouble-shooting simply diagnoses a malfunction. Such actions may provide immediate improvement in squadron ASW capability or shorten repair time but they do not represent a maintenance contribution since the original malfunction is not repaired but merely transfered to another aircraft or put off until later.

Malfunctions were discovered either in-flight or while the aircraft was on the ground. Table IV-1 displays the number of malfunctions for each squadron and the aircraft's environment when the malfunction was discovered. Those malfunctions discovered in the air represent the number of opportunities that the IFTs had to immediately increase the aircrafts ASW capability.

AVIONICS RELATED MALFUNCTION DISTRIBUTION

Aircrafts Environment	Squadron A	Squadron B
Ground	229	174
Air	165	147
TOTALS	394	321

Table IV-1

Table IV-2 presents a comparison of the malfunctions, expressed in percent, for both squadrons. It is apparent that the percentages of ground versus air discovered malfunctions is approximately the same for both squadrons.

PERCENTAGE OF GROUND VS AIR DISCOVERED MALFUNCTIONS

Aircraft Environment	Squadron A	Squadron B
Ground	58%	54%
Air	42%	46%
TOTALS	100%	100%

Table IV-2

B. SIGNIFICANCE OF MALFUNCTIONS

1. Malfunction Significance Categories

Further utilization of the data required the development of a procedure to determine the degree of ASW capability restored through the repair of a given discrepancy. This determination is an expression of the significance of the work done. Six significant categories were defined that ranged from 0 to 100% ASW degradation due to avionics related malfunctions. Six categories provided a small enough range within each category (16.7%) to yield a reasonably precise indicator of lost ASW capability but the category definitions were sufficiently broad to facilitate determination of the significance of specific malfunctions. While the range of ASW degradation around each category made it easier to categorize a given malfunction, the range was not satisfactory for analytical purposes. A specific percentage value, the midpoint of the range, was used to evaluate the significance of the malfunction. Table IV-3 displays the Malfunction Significance Categories, the range of lost ASW capability and the midpoint of each range associated with

each Category. A malfunction placed in Category Two would indicate that the malfunction caused a loss of 16.7 to 33.4% of the aircraft's ASW capability. Conversely, repair of that malfunction would recover the same amount of ASW capability.

MALFUNCTION SIGNIFICANCE CATEGORIES

CATEGORY	QUALITATIVE DISCRIPTION	RANGE	MIDPOINT
One	Minor	.01-16.7	8.35
Two	Moderate	16.7 -33.4	25.05
Three	Substantial	33.4 -50.1	41.75
Four	Serious	50.1 -66.8	58.45
Five	Critical	66.8 -83.5	75.15
Six	Catastrophic	83.6 -100	91.75

Table IV-3

2. Personnel Utilized in Malfunction Significance Categorization

It was decided that the P3C operators were the best qualified personnel to perform the categorization process. Two groups were selected to act as classifiers, IFTs and TACCOs. The IFTs were selected because of their expertise in regard to each system and the TACCOs because of their understanding of the interrelationship between various systems and the aircraft's mission performing capabilities. A panel of six TACCOs and six IFTs were selected from the two squadrons which provided data.

3. <u>Consolidating and Testing Opinion</u>.

a. Consolidating Opinion

Each malfunction was independently classified by each of the twelve panel members. They were given access to all relevant information except which squadron experienced the malfunction. When the panel was unable to reach a unanimous opinion as to the correct category for a given malfunction, the approximate category was selected on the basis of the average category classification of the twelve respondents. For example, if in the opinion of ten members, a particular malfunction was 'Minor' (Category One) and the remaining two members felt that it was more appropriately 'Moderate' (Category Two) then the average of the opinions would lie somewhere between Category One and Category Two, specifically 1.33; (8(1)+4(2)/12). Since 1.33 lies closer to Category One than Category Two, the malfunction would have been placed in Category One. Anytime that a malfunction had to be averaged it was placed into the nearest category. A malfunction determined to be exactly halfway between two categories was placed in the higher category of the two.

b. Testing Opinion

The possibility existed that the twelve opinions for a single malfunction would be spread across several of the categories available so that the average classification of the malfunction would not be valid. For example, if two responses placed a malfunction in Category One, two more in

Category Two, two in Category Three... all the way to Category Six such that the same malfunction had been listed twice in each of the six categories, the average for that malfunction would be computed to be Category Four. Using Category Four to represent the value for the significance of ASW degradation would be questionable since ten of the twelve respondents felt it belonged in another category. To ascertain that the above phenomenon had not occurred, a "goodness of opinion" test was designed. A randomly selected sample of malfunctions was examined to determine if the dispersion of responses for a given malfunction was so spread out among the six malfunction categories that identifying that malfunction with a specific significance category was erroneous. Another test was conducted to determine if the midpoint of a category (i.e. one, two, etc.) could be used as an estimator of the averaged opinions for a specific malfunction. Both hypotheses were accepted at the 95% significance level. Details of both tests and the sample of malfunctions considered are discussed in Appendix B.

c. Categorization of Data

Table IV-4 displays the Malfunction Significance Categories and the number of malfunctions for each squadron that were placed in those categories. It should be noted that in no case did the average of the respondents opinions place a malfunction in Category Six. Therefore, Category Six was eliminated from further utilization in the tables

that follow.

SUMMARY OF MALFUNCTIONS BY MALFUNCTION SIGNIFICANCE CATEGORY

CATEGORY	SQUADRON A	SQUADRON B	COMBINED
One	28	22	50
Two	112	102	214
Three	165	133	298
Four	47	36	83
Five	42	28	70
Six	0	0	0
TOTALS	394	321	715

Table IV-4

C. COMPARABILITY OF DATA SOURCES

Since data were obtained from two different squadrons, it was possible that basic differences existed which could significantly bias the apparent relative effectiveness of the two squadrons' maintenance programs. Differences in the proportion of significant malfunctions could permit one squadron's maintenance effort to appear more valuable by repairing more serious malfunctions. Also, differences in the total number of malfunctions experienced by each squadron could give the same false impression of relative maintenance productivity.

1. Distribution of Malfunctions In The Significance Categories

It was assumed that each squadron would experience the same relative numbers of malfunctions in each significance

category. To test the assumption the hypothesis was developed that there is no significant difference between percentage of malfunctions per category between Squadron A and Squadron B. Table IV-5 shows for each squadron the percentage of the total malfunctions experienced by that squadron that occurred in each category.

DISTRIBUTION OF MALFUNCTIONS (%)

SQUADRON	SIGNIFICANCE CATEGORY				
	1	2	3	4	5
A	7.0	28.4	41.8	11.9	10.6
B	6.8	31.8	41.4	11.2	8.7
% Difference	0.2	3.4	0.4	0.7	1.9

Table IV-5

The last row of Table IV-5, % Difference, displays the difference between squadrons in the percent of malfunctions per category. Through the use of the Chi-Square Test that difference was tested (Appendix C). It was found that the difference between the distribution of malfunctions in each category was not significant at the 95% level. Therefore, the assumption that each squadron experienced the same relative number of malfunctions per significance category was supported.

2. Adjustment to the Total Malfunctions Per Squadron

Since Squadron B experienced fewer malfunctions than Squadron A, (321 vs 394), the direct comparison of EAU recovered by the various groups (i.e. IFTs) would have been misleading due to the higher opportunity to repair malfunctions

in Squadron A. In order for the comparison of utilization of personnel in the two squadrons to be meaningful, the malfunctions data for squadron B was adjusted in each significance category to yield the same total number of malfunctions as experienced by Squadron A. Table IV-6, Adjusted Malfunctions, represents the normalization of the malfunctions in each category for Squadron B to make the total number of malfunctions in that squadron equal to the total in Squadron A.

ADJUSTED MALFUNCTIONS[(1)]

SIGNIFICANCE CATEGORY	SQUADRON A Actual	SQUADRON B Actual	SQUADRON B Adjusted[(2)]
One	28	22	27
Two	112	102	125
Three	165	133	164
Four	47	36	44
Five	42	28	34
TOTALS	394	321	394

Table IV-6

Notes:
(1) Adjusted Malfunctions = Actual x 394/321.
(2) Rounded off to nearest whole number.

Throughout the remainder of this thesis the adjusted number of malfunctions for Squadron B were used to compute EAUs recovered when comparisons of the two squadrons' personnel utilization policies were being made. Any time general comparisons of overall squadron policy were being made the actual

number of malfunctions for Squadron B were used to compute EAUs.

V. DERIVATION OF EQUIVALENT AIRCRAFT UNITS

A. EQUIVALENT AIRCRAFT UNIT (EAU) CONCEPT.

1. Components of The EAU Concept

The traditional manhours accounting system attempted to measure a worker's productive effort by the number of hours worked. The EAU concept combines the significance and the amount of the work that is done and then expresses the result as the number of EAUs recovered. Simply stated the EAUs recovered are a function of the significance of a malfunction and the number of malfunctions recovered. Those two components are defined as follows:

a. Significance of a Malfunction(S)

The higher the Malfunction Category into which a malfunction is placed the more significant the work that corrected the malfunction. The Malfunction Significance Table (Table IV-3) represented the EAUs that would be recovered for a single malfunction in each category. From Table IV-3 it is found that the repair of a single Category One malfunction (Minor) would recover .0835 EAUs.

b. Number of Malfunctions(N).

Table IV-6 displayed the other component of the EAU concept, namely the number of malfunctions (N) in a given significance category.

2. Computing An EAU

Based on the two components, Significance (S) and

the number of malfunctions (N), the EAU for a given Significance Category was computed as follows:

$$EAU = S \times N \qquad \text{(Equation V-1)}$$

For example, the EAUs recovered in Squadron B by the correction of all Category Two malfunctions (adjusted) would be found by multiplying the significance of a Category Two malfunction (S_2) times the number of Category Two malfunctions (N_2) corrected or:

$$EAU_2 = S_2 \times N_2$$

$$EAU_2 = (25.05\%) \times (125)$$

$$EAU_2 = 31.3$$

Therefore, the EAUs recovered by the Avionics Work Center in Squadron B due to the correction of Category Two malfunctions was 31.3 EAUs.

B. EVALUATING THE CONTRIBUTION OF A WORK GROUP

1. Contribution of A Work Group

The contribution of a particular work group (i.e. permanent ground personnel or In-Flight Technicians) was determined by establishing the proportion of malfunction repairs attributed to that group. The determination of the proportion of repairs was made by examining all of the MAFs within each Malfunction Category and noting, according to the worker's signature, who performed the work, an IFT or Permanent Ground Personnel (PGP). There are two signature blocks on a MAF that had to be examined, one for the worker and one for the supervisor. The assumption was made that

the worker and the supervisor contributed equally to the repair. Interviews of squadron maintenance personnel supported the validity of this assumption. The proportion of malfunctions (Q) repaired by a particular work group was established by dividing the number of signatures found on the MAFs for that group by the total number of signatures for workers of all the groups:

$$Q_{\text{(worker group)}} = \frac{\text{Signatures of that Group}}{\text{Total Signatures Recorded}} \quad \text{(Equation V-2)}$$

The determination of Q for Squadron B's PGP working in Category Two would be found by counting the number of PGP signatures (44) on the MAFs in that category and dividing that by the total number of Category Two signatures (72):

$$Q_{\text{PGP}} = 44 \div 72 = .61$$

Therefore, the proportion of work attributable to Squadron B's PGP by the repair of Category Two malfunctions was .61.

Q was computed for each work group of interest and listed by squadron and significance category in Table V-1.

2. Computing EAUs Recovered By a Work Group

Equation V-1 allowed the computation of EAUs recovered. Equation V-2 computed the proportion of work attributable to a particular work group. Combining both equations into Equation V-3 allowed the computation of the EAUs recovered by a specific group of personnel:

PROPORTION OF MALFUNCTIONS (Q) ATTRIBUTED TO IFT AND PGP

Malfunction Category	Total Mal	Ground Repair		In-Flight Repair	Totals	
		IFT	PGP	IFT	IFT	PGP
		(SQUADRON A)				
1	28	.375	.483	.142	.517	.483
2	112	.331	.598	.071	.402	.598
3	165	.379	.481	.140	.519	.481
4	47	.298	.574	.128	.426	.574
5	42	.369	.440	.191	.560	.440
		(SQUADRON B)				
1	22	.182	.773	.045	.227	.773
2	102	.239	.731	.030	.269	.731
3	133	.320	.635	.045	.365	.635
4	36	.377	.623	0	.377	.623
5	28	.303	.661	.036	.339	.661

Table V-1

EAUs RECOVERED BY PGP AND IFTs
IN THE REPAIR OF AVIONICS MALFUNCTIONS

Malfunction Category	Ground Repair		In-Flight Repair	Total EAUs/Wrk Grp	
	IFT	PGP	IFT	IFT	PGP
(SQUADRON A)					
1	0.877	1.129	0.332	1.209	1.129
2	9.287	16.777	1.992	11.279	16.777
3	26.108	33.135	9.644	35.752	33.135
4	8.817	15.769	3.516	12.333	15.769
5	11.647	13.888	6.029	17.676	13.888
TOTALS	56.736	80.698	21.845	78.581	80.698
(SQUADRON B, ADJUSTED)					
1	0.410	1.743	0.101	0.511	1.743
2	7.484	22.889	0.939	8.423	22.889
3	21.910	43.478	3.081	24.991	43.478
4	9.696	16.022	0.000	9.696	16.022
5	7.742	16.889	0.920	8.662	16.889
TOTALS	47.242	101.021	5.041	52.283	101.021
(SQUADRON B, UNADJUSTED)					
1	0.334	1.420	0.083	0.417	1.420
2	6.107	18.678	0.767	6.874	18.678
3	17.769	35.260	2.499	20.265	35.260
4	7.933	13.109	0.0	7.933	13.109
5	6.776	13.909	0.758	7.134	13.909
TOTALS	38.919	82.376	4.107	42.626	82.376

Table V-2

$$EAU_{(work\ group)} = S \times N \times Q \qquad \text{(Equation V-3)}$$

Q is taken from the appropriate category in Table V-1. To determine the EAUs recovered by PGPs in Squadron B by the repair of Category Two malfunction Equation V-3 was used as follows:

$$EAU_{PGP} = S_2 \times N_2 \times Q_2$$

$$EAU_{PGP} = (25.05)\ (102)\ (.731)$$

$$EAU_{PGP} = 18.7$$

Therefore, Squadron B's PGP recovered 18.7 EAUs by the repair of Category Two malfunctions. Table IV-2 represents the EAUs recovered by the PGPs and IFTs (both in work center 210 and X20) for Squadron A and Squadron B.

C. THE VALUE OF IN-FLIGHT REPAIRS

1. Rationale For Increasing the Value of In-Flight Repairs

Table V-2 displayed the EAUs recovered by IFTs working while airborne. Those figures may not be meaningful for all levels of squadron management. For example, a discrepancy that occurs and is repaired in the air during the prosecution of a submarine could very well have far greater value to the flight crew and the Commanding Officer than it would if fixed on the ground. Conversations with squadron Commanding Officers revealed that they do place more value on the repair of a discrepancy in-flight. In order to consider this added worth when investigating IFT work output at the Squadron Level an upward adjustment was

made to the values associated with each Malfunction Category.

2. Estimating The Value

To establish the needed adjustments it was necessary to determine the Commanding Officers' perceptions of the added value of in-flight repairs within each Category. An index of this added worth was developed through the use of a modified Delphi Technique.[7] An initial estimate was made by providing both squadron Commanding Officers with a list of the various Malfunction Categories and asking each to separately give his best estimate of how much more each Malfunction Category was worth to him if repaired in-flight. The Commanding Officers were then presented with their opposite's estimate and, without being informed who the other 'expert' was, were allowed to adjust their initial figures. This process was repeated until they agreed to the additional worth for each Malfunction Significance Category. Table V-3 displays the results of this process.

ADDITIONAL WORTH OF A MALFUNCTION CORRECTED IN-FLIGHT

Malfunction Significance Category	Worth Adjustment
0 (No Effect)	0
1 (Minor)	1
2 (Moderate)	2
3 (Substantial)	4
4 (Serious)	7
5 (Critical)	10
6 (Catastrophic)	15

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[7]Quade, E.S. and Boucher, W.I., Systems Analysis and Policy Planning, American Elsevier, 1968.

In applying this index, the EAUs recovered in a particular in-flight Significance Category were multiplied by the appropriate index value. For example, the worth of the in-flight repair of a Significance Category Three malfunction is four times the EAUs recovered by the repair of that same malfunction on the ground.

It must be noted that only two Commanding Officers were available to participate in the Delphi process. The result obtained has limited quantitative application, but does serve to illustrate the magnitude of the value of in-flight repairs.

3. <u>Adjusted EAUs for In-Flight Malfunction Repair</u>

Table V-4 displays the adjustment made to the EAUs recovered in-flight to reflect the additional value those repairs may represent to the Commanding Officer. Because of their limited quantitative validity, value-adjusted EAUs were carefully identified when used in later analysis.

VALUE-ADJUSTED EAUs RECOVERED IN-FLIGHT

(SQUADRON A)

Malfunction Categories	Additional Worth	EAUs Recovered In-Flight Unadjusted	Adjusted
1	1	0.332	0.332
2	2	1.992	3.984
3	4	9.644	38.576
4	7	3.516	24.612
5	10	6.029	60.290
	TOTALS	21.513	127.794

(SQUADRON B)

Malfunction Categories	Additional Worth	EAUs Recovered In-Flight Unadjusted	Adjusted
1	1	0.101	0.101
2	2	0.939	1.878
3	4	3.081	12.324
4	7	0.0	0.0
5	10	0.920	9.200
	TOTALS	5.041	23.503

Table V-4

VI. ANALYSIS OF ALTERNATIVES

A. GENERAL

The alternative uses for the Maintenance Department's avionics maintenance personnel fell into two general categories: use within the squadron and use outside of the squadron. The alternatives for use within the squadron involved two separate areas, altering the IFT in-flight utilization policy (short run alternatives) and changing the composition of the entire Maintenance Department avionics work force (long run alternatives). The information collected during this investigation was evaluated to determine each alternative's potential contribution to the squadron's mission performing capability.

The study of avionics maintenance personnel use outside of the squadron addressed only the IFT. The alternatives for IFT use outside of the squadron consisted of the possible mixes of IFT assignment between the squadron and Intermediate Level maintenance activities and the squadron and Depot Level maintenance activities. Since the Intermediate and Depot Level maintenance information needed to estimate EAUs was not readily available, the analysis of these alternatives was qualitative in nature.

B. IFT IN-FLIGHT UTILIZATION POLICIES

The evaluation of the short run alternatives entailed studying the IFT allocation between Work Centers 210 and

X-20 in order to determine how the Maintenance Department may best contribute to the squadrons' mission performing capability. Since the composition of the Maintenance Department's avionics work force cannot be changed in the short run, this was a constant cost problem in which various IFT allocations were compared on the basis of EAUs recovered. The IFT utilization methods followed by the two squadrons that were studied offered an opportunity for a real-world examination of the effectiveness of two differing IFT allocation policies. Squadron A's IFT utilization policy involved flying IFTs only on operational flights whereas Squadron B chose to fly IFTs on virtually all missions. Since IFT in-flight utilization (Work Center X-20) varies inversely with their use in Work Center 210, Squadron A had a greater number of IFTs available to perform ground maintenance. The contribution of the IFT's within each Maintenance Department to the squadron's ASW capability was determined using the EAU as a measure of effectiveness. The results are shown in Table VI-1. $X\text{-}20_{wt}$ represents the in-flight contributions weighted through use of the Commanding Officer's additional worth multiplier developed in Chapter V and $Total_{wt}$ represents the weighted IFT total which equals $X\text{-}20_{wt} + 210$. Adjusted EAUs were used for Squadron B.

IFT RECOVERED EAUs WEIGHTED AND UNWEIGHTED

Organization	210	X-20	$X\text{-}20_{wt}$	Total	$Total_{wt}$
Squadron A	56.7	21.8	127.8	78.5	184.5
Squadron B	47.2	5.0	23.5	52.2	70.7

The results clearly indicate the superiority of the IFT allocation policy followed by Squadron A. The most surprising information in Table VI-1 is the unexpected difference in the X-20 EAUs recovered between the squadrons. This difference is further magnified after application of the Commanding Officer's additional worth multiplier. The low X-20 figure for Squadron B may best be explained as a documentation problem. During the investigations conducted at the squadron there were no indications that the squadron's IFTs engaged in in-flight maintenance were performing at an unacceptably low level. However, documentation of in-flight maintenance has historically been a problem in many squadrons. Most in-flight repairs involve adjustments or alignment and take only a short time to accomplish. Since documenting the work often consumes nearly as much time as performing the repair, IFTs occasionally have had a tendency to fail to complete MAFs for quick repairs, even though the repairs may be very significant in terms of recovered capability.

It was expected that Squadron A IFTs working in Work

Center 210 would provide a greater contribution to the squadron's ASW capability since, because of the squadron's IFT in-flight utilization policy, there were more IFTs available for Work Center 210 assignment than in Squadron B. This increased contribution did occur. It was also expected that Squadron B, because of flying IFTs on all flights, would experience a greater degree of recovered ASW capability through Work Center X-20 repairs. The intended purpose of examining these two IFT utilization policies was to see if the expected decrease in the contribution made by Squadron B's IFTs in Work Center 210 would be offset by the expected increase in the contribution made by its additional IFTs in Work Center X-20 and how application of the Commanding Officer's additional worth multiplier would affect the trade-off. However, since the expected increase in Squadron B's X-20 contribution was not realized, no firm conclusions could be made regarding the offsetting effects associated with varying the allocation of IFTs between Work Centers X-20 and 210.

C. CHANGES IN THE MIX OF IFTs AND PERMANENT GROUND PERSONNEL

1. General

In the long run the numbers of IFTs and ground personnel within the Maintenance Department may be altered. As both groups have the same background of basic avionics training, many avionics repairs could be performed equally well by either group. However, IFTs, are a more expensive resource than ground personnel because of their higher pay

grades, flight pay, and additional training costs. Thus, if the ratio of ground personnel to IFTs could be changed by increasing the proportion of ground personnel without degrading the Maintenance Department's contribution to the squadron's mission performing capability then this change would result in a more efficient use of Navy manpower.

2. Analysis of Changes to the Mix of IFT/Ground Personnel

To evaluate the effects of changes to the mix of IFTs and ground personnel in Work Center 210 it was necessary to establish a basis for comparison of the contributions of individual workers. The average EAUs recovered per worker was used for this comparison. Since the EAUs recovered by in-flight repairs will not be affected by a change in the mix of IFTs and ground personnel as long as a squadron is given enough IFTs to follow its IFT in-flight utilization policy, EAUs recovered in the air were not considered in this portion of the analysis.

There were 15 ground personnel assigned to Work Center 210 in each squadron. There were 13 IFTs assigned to each squadron but, because of the squadrons' differing IFT in-flight utilization policies, the number of IFTs available for assignment to Work Center 210 was not the same in each squadron. The number of IFTs required for use in Work Center X-20 is equal to the average number of daily flights for those types of flights associated with a particular IFT in-flight utilization policy. For example, squadron B flew IFTs on all flights and had a daily average

of 5.11 flights, each requiring one IFT. Therefore, since 13 IFTs were assigned to the squadron, 7.89 were available for utilization in Work Center 210.

The number of EAUs recovered per man in Work Center 210 was determined based on the actual number of malfunctions, since the adjusted number of malfunctions developed for Squadron B would misrepresent the actual productivity per worker. Table VI-2 indicates the number of IFTs and PGPs assigned to Work Center 210 in each squadron and the actual number of EAUs recovered by each work group.

WORK CENTER 210 MANPOWER AND EAUs

	Actual Manpower			EAUs Recovered		
ORGANIZATION	IFTs	PGP	Total	IFTs	PGP	Total
Squadron A	11.66	15	26.66	56.7	80.7	137.4
Squadron B	7.89	15	22.89	38.9	82.4	121.3
Squadron A & B	19.55	30	49.55	95.6	163.1	258.7

Table VI-2

Utilizing the data from Table VI-2, the EAUs per man were calculated for each work group in each squadron. The resulting average productivity per man in various groups is shown in Table VI-3. Analysis of the average productivity per man indicated that Squadron B's Work Center 210 personnel, with an output of 5.30 EAUs per man, were performing at a higher level than those in Squadron A, whose output was

5.15 EAUs per man. Two possible explanations for this superior performance were considered.

EAUs PER MAN

Organization	Total Work Center EAUs per man	IFT EAU per man	PGP EAU per man
Squadron A	5.15	4.86	5.38
Squadron B	5.30	4.93	5.49
Combined Average	5.22	4.89	5.44

Table VI-3

First, Squadron B operated with a more efficient mix of IFTs and ground personnel. Overall, IFTs recovered 4.89 EAUs per man while ground personnel recovered 5.44 EAUs per man. This difference in productivity, when considered with the cost differential between IFTs and ground personnel, indicated that an increase in the proportion of ground personnel assigned to Work Center 210 would be more cost effective. Squadron B's increase in the proportion of ground personnel was accomplished through the reduction of IFTs in Work Center 210 due to the policy of using IFTs on all flights.

Second, Squadron B achieved a level of performance closer to the capacity of its personnel. With fewer total

personnel, Squadron B's IFTs and ground personnel each out-produced their counterparts in Squadron A. This indicated that Work Center 210 personnel in Squadron A were under-utilized compared to those personnel in Squadron B. However, this did not imply that Squadron B personnel were producing at full capacity. In fact, further reduction in IFTs assigned to Work Center 210 may have lead to additional improvement in individual work output.

It appears that cost savings could be realized without reducing maintenance capability through the replacement of some IFTs with ground personnel. Since the analysis was not sufficient to determine the workers' full capacity, no numerical estimate could be made regarding the number of IFTs to be replaced by ground personnel.

3. Other Considerations

Although the results of this analysis provide a persuasive argument for reducing the number of IFTs assigned to P3C squadrons, there are other factors which should be considered before implementing such a change.

First, it must be noted that the EAUs per IFT and ground avionics worker are representative of average, not marginal, contributions to ASW capability. Thus, if a squadron operated in the area of diminishing returns and the average EAUs per ground worker was 5.44, one additional worker would contribute less then 5.44 EAUs. The data indicated that for IFTs the squadrons were operating in the area of diminishing returns. Squadron A, with an increased

number of IFTs, experienced a decreased incremental contribution to the squadron's mission performing capability. This tended to support the recommendations to decrease the number of IFTs available in Work Center 210. However, the available data did not permit a determination of the incremental contribution of ground personnel. Thus it was not possible to show that the marginal returns of ground personnel were diminishing, constant, or increasing.

Second, before any substitutions of ground personnel for IFTs can be considered, an examination must be made of their relative capabilities. Since IFTs and ground personnel receive training on different portions of the avionics systems, total substitution of IFTs and ground personnel is not possible. However, there is a great degree of cross-training between IFTs and ground personnel which diminishes the differences in their ground repair capabilities. An examination of ground repairs (Appendix D) indicated that IFTs dominate the repair effort on only two portions of the avionics systems. This appears to indicate that except for those two sub-systems, ground avionics personnel are as capable as IFTs. However, this may be an inaccurate representation of worker capabilities. The investigation of system repairs was made by examining the two worker signatures on the Maintenance Action Form filled out for each repair. If the repair was performed by a ground worker and an IFT, each was assumed to possess the same capability on that system. This may not be true because one worker could

have been training another far less capable man. Therefore, before any definite worker substitutions are considered, a closer examination of the requirements for work skills is necessary.

Third, there must be sufficient IFTs assigned to a squadron to man the maximum number of flights as dictated by the squadron's operating policy. This places a floor on the number of IFTs that may be deleted from the squadron's manning requirements and replaced by ground personnel.

Finally, there is an additional barrier to decreasing the number of squadron IFTs. It is known as the 'crew concept'. Historically, the P3C aircrew, including the IFT, has been viewed as a team that operates as a unit with each member aware of his teammates shortcomings and strong points. Since there are eleven crews per squadron it may not be likely that a Commanding Officer would endorse the assignment of less than eleven IFTs, one permanently attached to each aircrew.

D. THE IN-FLIGHT MAINTENANCE KIT

1. Background

The introduction of the P3C aircraft with its self-test, computerized ASW systems established elevated standards of maintainability and reliability within the P3 community. This unique weapon system also ushered in a new philosophy of avionics and related systems maintenance, the pull-out and plug-in or "modular repair" process. The emergence of the "modular repair" concept led to the

instatement of IFTs as flight crew members and to the placement of onboard spare parts (spare modules) aboard the P3C aircraft. This onboard supply of spare parts was labeled the "in-Flight Maintenance Kit" (IFMK). The inventory of the IFMK dictates, to a great degree, the effectiveness of the IFT during airborne missions. With a well engineered IFMK and a skilled IFT aboard the aircraft, the Patrol Plane Commander should be fairly confident that he will successfully complete his ASW mission in spite of normal avionics hardware malfunctions. The inventory of the IFMK is very important. The cost of training an IFT plus the added expense of his flight pay substantiates the need for supplying him with the assets necessary to be as productive as possible in the air. The Initial Outfitting List for kits such as the IFMK is usually based upon failure rates projected by the system manufacturers and is normally adjusted later after operational failure rates have been established.

2. Analysis of In-Flight Malfunctions

This analysis utilized only those malfunctions involving the removal and replacement of a piece of electronics equipment or a component part. Such malfunctions can be identified by the indication of a part number on the MAF. Maintenance actions such as trouble-shooting, adjusting, tuning and cleaning do not involve component replacement. The malfunctions identified for this analysis, displayed in Table III-12, show that there were a total of 381 avionics

malfunctions in both squadrons involving part numbers. Of these, 259 were discovered on the ground (during pre-flight inspections and other periodic inspections) and 122 were discovered in-flight. The vast majority of ground discovered malfunctions are repaired on the ground. To simplify the analysis, it was assumed that all malfunctions discovered on the ground were also repaired on the ground. Air discovered malfunctions may be repaired by the IFT at the time of discovery or repair may be postponed and affected upon return to the ground. It is reasonable to assume that some percentage of repair would be achieved in the air for air discovered malfunctions. However, as indicated by Table VI-4 , none of the 122 air discovered malfunctions involving part numbers were repaired in-flight. This represented a significant deficit in the effectiveness of in-flight maintenance, possibly due to inadequacies of the IFMK. To further emphasize the importance of this deficit it should be noted that most of the 69 malfunctions falling into Malfunction Categories 3, 4, and 5 of Table VI-4 were individually severe enough to have caused a mission abort or aircraft change if discovered during pre-flight. These malfunctions, which occurred but were not repaired in-flight, thus caused large degradations in ASW capability during missions.

AVIONICS MALFUNCTIONS REQUIRING COMPONENT REPLACEMENT

Malfunction Categories	Ground Discovered/ Ground Repaired	Air Discovered Air Repaired	Air Discovered Ground Repaired
One	14	0	7
Two	65	0	46
Three	117	0	39
Four	39	0	12
Five	24	0	18
TOTALS	259	0	122

Table VI-4

3. Revision of the IFMK

In order to determine what sub-systems/components should be added to or supplemented within the current IFMK, the frequency of subsystem/component in-flight failure and the significance of those failures was examined. Table VI - 5 indicates the sub-systems/components involved in the 122 in-flight malfunctions of Table VI - 4, in descending order of their frequency of occurrence. The significance of each sub-system/component is indicated by the potential EAU's recoverable had that sub-system/component been available to the IFT for immediate replacement. There were 19 sub-systems that failed two or more times during the two month period examined. Immediate repair of these malfunctions would have recovered 28.6 EAU's in-flight. In addition, 54 other sub-systems failed once during this period. One-time

failures from the small sample available were not considered sufficient justification for augmentation of the IFMK. However, the EAU's recoverable for these additional failures is large and cannot be overlooked and, therefore, were indicated in Table VI-5

POTENTIAL CONTRIBUTION OF EXPANDED IFMK

Sub-system/Component	In-Flight Malfunctions	EAU's Recoverable
1. APN 187,2A1 module	14	5.845
2. APN 141,RT601	7	4.092
3. ARN 52, Phse Dtctr	5	2.087
4. AIC 22, AM4964	5	1.252
5. APS 115,7A1 module	4	1.670
6. AQA 7, 1Aseries mdls	4	1.670
7. APN 141, SA791	3	1.754
8. AQA 7, MX8439	3	1.252
9. APX 76, RT 868	3	1.252
10. ARC 143, 1A1 mdle	2	.835
11. ARC 143, 1A2 mdle	2	.835
12. KW7/KY28, Rmt Cntrl	2	1.169
13. ASA 66, IP886	2	.835
14. ARR 72, SG791	2	.835
15. AQH 4, MX8534	2	.835
16. APN 187, RT890	2	.835
17. AIC 22, C8242	2	.501
18. AIC 22, AM3364	2	.501
19. ARN 87, CV2059	2	.501
SUBTOTAL	68	28.556
Other Sub-system Failures	54	19.202
TOTAL	122	47.758

Table VI-5

4. The Effect of Increased Productivity in Flight

As indicated in Table VI-5, there were a total of 19 specific sub-systems/components that accounted for over 28 recoverable EAUs. Therefore, approximately 14 additional EAUs could be contributed to the in-flight maintenance productivity of each squadron through the incorporation or supplementation of these 19 components in the current IFMK. The result of this increase of in-flight EAUs would be a corresponding decrease of 14 EAUs in the output required of each squadron's ground maintenance program. This may make possible reductions in the manpower requirements in Work Center 210. Based upon the analysis in Section C of this chapter, the productivity of the avionics ground personnel was superior to the IFTs and the cost of an IFT was considerably higher than ground personnel. In light of these factors it appears most efficient to begin a reduction in force level with the IFTs. Determination of the magnitude of this reduction was not within the scope of this thesis.

5. Limitations

The IFT, because of his skill level and training, is the one technician in the Avionics Work Center who is qualified to effect any organizational level repair. It was concluded that the limiting factor to IFT effectiveness in-flight was the adequacy to the IFMK. Through discussions with squadron and COMPATWINGPAC maintenance personnel there was conveyed a genuine concern for the inadequacy of the

current IFMK aboard the fleet's P3C aircraft. The preceeding analysis supports this concern. However, the conclusions developed are based on a relatively small sample and cannot be considered conclusive. A similar analysis examining a longer operational period and additional squadron maintenance activities could be very useful in determining the needed inventory adjustments in the current IFMK. Such an analysis should also include considerations of additional cost, space and weight required by an expanded IFMK. It should also consider factors other than IFMK inadequacies which may limit the ability of the IFT to perform in-flight repairs. Factors such as the adverse effect on related systems associated with turning off and trouble-shooting the faulty system and accessibility during flight of the faulty system or component were beyond the scope of this thesis but should be included in a complete review of the IFMK.

E. IFT UTILIZATION AT INTERMEDIATE AND DEPOT LEVEL MAINTENANCE ACTIVITIES

1. General

Since P3C avionics systems are repaired at the Depot and Intermediate Levels, potential IFT ASW capability contributions in those areas was investigated. The EAU was not used as a measure of effectiveness for this evaluation because of the unavailability of Intermediate and Depot Level data. For that reason, the examination of IFT utilization at Intermediate and Depot Level maintenance activities was qualitative in nature.

2. <u>IFT Assignment to Intermediate Level Maintenance Activities</u>

Intermediate Level maintenance is performed at Aircraft Intermediate Maintenance Departments (AIMDs). The AIMD is one of the departments in the organizational structure of the Naval Air Station from which P3C squadrons operate. Intermediate Level maintenance is performed by personnel permanently assigned to the AIMD and by squadron ground personnel who are assigned to the AIMD on a temporary basis. AIMD work centers are organized and staffed in the same manner as the squadron Maintenance Department work centers. The AIMD supports the squadron Maintenance Department through trouble-shooting and repair of those systems removed from the aircraft by maintenance personnel within the squadron.

When an item is removed at the squadron, a replacement item is requisitioned from the base Supply Department. If available, the replacement part is issued to the squadron immediately. The faulty item may be inducted into the AIMD for repair on a routine work priority if the AIMD has the necessary repair capability for that item. If no replacement is available, the defective item is also inducted into the AIMD for repair but on a higher work priority. If the initial requisition was submitted with a supply priority of two, which indicates the highest urgency of need by the squadron for the replacement part, Production Control personnel at the AIMD would schedule the defective

component into work immediately. Because of the importance of priority two items, it is the AIMD policy to call workers in during off-duty hours, as necessary, to perform the needed repairs.

Due to the high work priority assigned to urgently needed avionics systems by AIMD and since there is rarely any backlog of such items awaiting work, the gains associated with the assignment of IFTs to Intermediated Level maintenance activities were considered negligible. It was concluded that the policy of not assigning IFTs to AIMD is satisfactory.

3. <u>IFT Assignment to Depot Level Maintenance Activities</u>

There are systems aboard the P3C whose failure rates and complexity are such that it was not feasible to establish a repair capability at the local AIMD. Also, there are occasions on which a system or component is damaged to such an extent that it may best be repaired at a Depot Level maintenance activity, even though some repair capability exists at the AIMD. These systems, along with defective sub-assemblies and circuit boards identified and replaced at the AIMD during normal repair, are shipped to and repaired at Depot Level maintenance activities.

Depot Level maintenance of airframe and powerplants items is normally performed at Naval Aircraft Rework Facilities (NARFs). Periodic aircraft overhaul is also performed at the NARFs. Depot Level maintenance for the P3C avionics and electrical systems is performed at individual equipment contractor sites on 'Repair of Repairable' type

contracts. Once repaired, the systems, sub-systems and sub-assemblies are packaged and shipped to the original requisitioning activities.

The only gain to be made through assignment of IFTs to a contractor site lies in a potential decrease in the supply pipeline time from squadron to contractor and back to the squadron. However, the bulk of the time consumed between an item leaving and returning to the squadron is comprised of packaging, shipping and transportation delays, not in contractor repair time. Thus, the potential for IFT contributions is negligible and IFT assignment to Depot Level maintenance activities is not recommended.

VII. CONCLUSIONS

A. SUMMARY

The purpose of this thesis was to evaluate various methods of avionics maintenance manpower utilization, with the emphasis placed on the allocation of IFT work effort, by conducting an analysis of the effectiveness of the avionics maintenance program in operational P3C squadrons. In place of using manhour analysis, a traditional method of measuring worker effectiveness, a new measure of effectiveness was developed. That new measure of effectiveness, termed the "Equivalent Aircraft Unit", measured maintenance productivity in terms of the significance of a malfunction and the number of malfunctions repaired.

In the course of this analysis, conclusions and recommendations were generated that fall into two general categories: (1) Those that affect management policies under the control of squadron Commanding Officers and, (2) Those that concern policies developed at higher levels of command. These two categories are discussed below.

B. RECOMMENDATIONS FOR SQUADRON POLICY

The Commanding Officer has a great deal of control concerning the use of personnel once they are assigned to his squadron. For example, he may effect changes in Work Center 210 by increasing or decreasing the number and type of missions on which IFTs must fly. The Commanding Officer

of one squadron examined elected to fly IFTs only on operational missions, which resulted in more personnel on the ground working in Work Center 210. However, the Commanding Officer of another squadron chose to fly IFTs on all flights, thus decreasing the personnel available to Work Center 210. Evaluation of these policies led to the following recommendation:

1. The IFT in-flight utilization policy should entail flying IFTs only on operational missions, with the remainder of their time spent performing avionics maintenance in Work Center 210.

C. RECOMMENDATIONS FOR POLICY AT HIGHER LEVELS OF COMMANDS

Areas examined that concerned policies made at higher levels of command included: changing the mix of IFTs and Permanent Ground Personnel assigned to P3C squadrons, utilizing IFTs at higher levels of maintenance than the Organizational (squadron) Level, and modifying by addition or deletion, the standardized items of avionics equipment that constitute the IFMK. The following recommendations were made:

1. The number of IFTs assigned to a P3C squadron should be reduced with a corresponding increase in the number of assigned ground personnel.

2. IFTs should not be assigned to Intermediate and Depot Level maintenance activities.

3. The IFMK should be augmented by the inclusion of certain high failure components after consideration of the cost, size, and weight of those components.

D. AREAS FOR FURTHER STUDY

1. The ASW capability contributions of other Maintenance Department work centers could be evaluated using EAUs as the measure of effectiveness. This would provide comparability of the outputs of all work centers.

2. An examination of the IFMK is needed to determine which specific components should be included based on component cost, size, weight and potential contribution to system capability.

3. A comparison could be made of EAUs and man-hours to determine which is a better measure of effectiveness for determining the Maintenance Department's contributions to the squadron's ASW capability.

APPENDIX A

INFORMATION AVAILABLE FROM A MAINTENANCE ACTION FORM

The Maintenance Action Form (MAF) was the source document for data collection for this thesis. The following data was available on each MAF:

1. JCN-Job Control Number: serializes and identifies each maintenance action.

2. DISC-When discovered code: identifies when each malfunction was discovered (pre-flight, in-flight, etc.).

3. ACT-Action taken code: describes the corrective action required to complete the repair (trouble-shoot, remove and replace, align, etc.).

4. MAL-Malfunction Code: describes the nature of the discrepancy (out of tolerance, burned out, shorted, etc.).

5. WUC-Work unit code: identifies the system, sub-system or component affected by the malfunction (i.e. 1A1 module of AQA-7 system).

6. P/N-Part number: utilized only when the repair was accomplished by the replacement of a part, it identifies the part removed and replaced.

7. W/C-Work Center-identifies the work center to which the personnel who repaired the malfunction were assigned.

8. M/H-Man-hours: Total man-hours expended during the repair.

9. Accomplished by/Supervised by-signatures of the

individuals who performed the repair action (this block is the only means to differentiate between an IFT working on the ground and a PGP.

10. Discrepancy-Written description of the malfunction.

11. Corrective action-Written description of the required repair action.

APPENDIX B

Tests of Hypotheses in the Classification of Data[1]

Two hypotheses were tested regarding the placement of a malfunction within a given Malfunction Significance Category.

1. Hypothesis: The mean classification of a malfunction selected at random ($\bar{x}$) would be close enough to the number of a Malfunction Significance Category for that number to be used as the Mean (μ_o) for all malfunctions that fall in that category. The hypothesis was tested at the 97.5% significance level ($t_c = 2.20$) by use of the t-test such that the specific hypothesis (H) was $H: \mu = \mu_o$ and

$$t = \frac{\sqrt{N}\ (\bar{x}-\mu_o)}{S} \qquad \text{(Eq. 1)}$$

Where: $\bar{x}$ = mean classification computed for a single malfunction

μ_o = the number of the Significance Category concerned

S = standard deviation from μ_o

N = total number of respondents = 12

If for example a malfunction has been classified by the twelve respondents as Category three based on a distribution

[1]Ostle, Bernard, Statistics in Research, Iowa State University Press, Ames Iowa, USA (1963).

of nine respondents placing the malfunction in Category Three, two respondents placing the malfunction in Category Four and the remaining respondent selecting Category Two, $\bar{x}$ would be computed to be 3.08 and the standard deviation (S) would be .5. The category number of interest would be 3 ($\mu_o = 3$). Utilizing Eq. 1 it is found that

$$t = \frac{3.08-3.00\sqrt{12}}{.5} = .55$$

which falls in t_c interval of -2.20 to 2.20. Therefore, the hypothesis that the mean classification of the above malfunction is adequately represented by the Category number three cannot be rejected.

The above test was conducted for 10 malfunctions within each of the five Malfunction Significance Categories and the hypothesis ($H:\mu = \mu_o$) was accepted for each at the 97.5% significance level.

2. Hypothesis: The dispersion of a malfunction classifications by the twelve respondents over the available categories was small enough to justify the utilization of a specific category as representative of the majority of the respondents. The measure of dispersion was the standard deviation of the 12 responses. It was expected that for the sample of malfunctions examined, the standard deviations (μ) would be less than .75 at the 95 percent significance level ($t_c = 1.68$). The specific hypothesis ($H:\mu \leq .75$) was tested by

$$t = \frac{(\bar{x}-\mu_o)}{S_{\bar{x}}}$$

Where: $\bar{x}$ = the mean of the sample standard deviation

μ_0 = .75

$S_{\bar{x}}$ = the standard deviation of the sample mean ($\bar{x}$)

N = 50

A sample of 50 (N) malfunctions was selected. The mean of the standard deviations ($\bar{x}$) was .57, the standard deviation of the sample means ($S_{\bar{x}}$) equaled .139. Therefore,

$$t = \frac{.57-.75}{.139}$$

$$= 1.29$$

which is less than the t_c of 1.68. Therefore the hypothesis that $\mu \leq .75$ cannot be rejected.

APPENDIX C

Chi-Square Test for Significant Differences[1]

The Chi-square test was used to test the agreement between the number of observed malfunctions per category in Squadron A and B. To investigate the significance of the difference between the observed frequency of malfunctions in Squadron A with those observed in Squadron B, the use of the Chi-square test for goodness of fit[1] was utilized such that:

$$\chi^2 = \sum_i \frac{(A_i - B_i)^2}{B_i} \qquad \text{Eq. 1}$$

Where: $A_{(i)}$ = the frequency of malfunctions per category in Squadron A

$B_{(i)}$ = frequency of adjusted malfunctions per category in Squadron B.

χ^2 was tested at the 95% level of significance ($\chi^2_{.95}$ = 124.3) and the hypothesis that the difference between the malfunctions per category in Squadron A and B was insignificant could not be rejected.

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[1]Spiegel, Murray R., Statistics, McGraw-Hill Book Company, New York, N.Y., (1961)

APPENDIX D

Relative Capability of IFTs and PGP

In order to evaluate the relative ability of IFTs and ground personnel to repair different avionics sub-systems, an examination was made of sub-system repairs and a determination made of the percent of repairs for each sub-system that were performed by the two work groups. This was accomplished by noting who signed the 'Accomplished by' and 'Supervised by' block on each MAF. If there were ten repairs for a given system there would be twenty signatures, ten workers and ten supervisors. If twelve of the signatures were IFTs and eight were ground personnel then IFTs were considered to have performed 60% of the repairs and ground personnel the remaining 40%. The results of the investigation are shown below:

System	Percent Repaired by	
	IFTs	PGPs
KW-7	.40	.60
Signal Data Converter	.40	.60
ARC-101	.20	.80
ARN-87	.64	.36
Tactical Display	.32	.68
Radio Navigation Indicator	.58	.42
Flight Director Indicator	0	1.00
APX-76	.44	.56

System	Percent Repaired by	
	IFTs	PGPs
APN-141	.19	.81
Magnetic Tape Transport	.53	.47
Intercommunications System	.38	.62
AQH-4	.38	.62
AQA-7	.46	.54
ARN-52	.39	.61
APS-115	.28	.72
MAD	.5	.5
HF Communications	.28	.72
ASQ-114	.29	.71
Teletype	.08	.92
ACQ-5	.74	.26
ARR-72	0	1.00
APN-187	.21	.79

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